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X-RAY SWITCHING STUDIES ON CADMIUM IODIDE POLYMER COMPOSITES

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ABSTRACT

Composites of cadmium iodide were prepared using polymers Poly-methyl-methacrylate,Poly-carbonate, Poly-Styrene and Silicon Rubber with 50% by weight as matrix materials. Sheets of these composites were subjected to X-ray switching studies. These were found to have stable X-ray sensing and low on and off time during switching.

KEYWORDS –X-Ray Sensor, Polymer Composites, Switching, High Energy Smart Materials, Imaging

INTRODUCTION

Digital X-ray imaging is one of the most important technologies in modern diagnostics. One of the applications is in radiovisiography (RVG). This is the latest technique in X-ray imaging. In this technique X-rays are passed through an object and X- image is converted into an optical image with the help of a detector and recorded digitally [1-4]. Some of the advantages of this technology are

1. It reduces the X-ray dose to the patient up to 80%.
2. This method is superior to convention method of recording on an X-photographic film due to fast and reliable technique and bypassing chemical processing.
3. It is quick and provide image immediately.

4. Digital image can be processed and analyzed for minor details.

In order to record best image it is essential to have quick switching of X-rays. For this basic X-ray detector material should have quick response bothwhen X-rays are on and off.Cadmium iodide is found to be good X-ray detector material [5]. However, single crystals of this material are very soft. In order to enhance its mechanical properties composites are best option [6]. It is planned to use polymers as matrix material for cadmium iodide. Polymers provide additional strength and flexibility in shape of such detectors.

EXPERIMENT

Cadmium iodide (99% LobaChemie) is used as base material.Powder of cadmium iodide is dried and kept in a quartz boat surrounded by corning glass tube. Although cadmium iodide is most anhydrous of metal halides, it does contain a small amount of water vapors, causing oxide formation and consequent sticking of ingot to the container walls. Further in order to minimize reaction of cadmium iodide with gases in the surrounding, pure argon is continuously allowed to flow in surrounding of the boat containing cadmium iodide. It also helps to suppresses the evaporation and prevent oxidation. Thermal heating is used to melt the material in a narrow zone (around 2-3mm). Zone is slowly taken to one side at slow rate (about 1cm/hr). After repeated 20 zone passes, impurities are found to collect at the end of the ingot [Fig1(a)]. Initial portion of the ingot is used to prepare the composites.

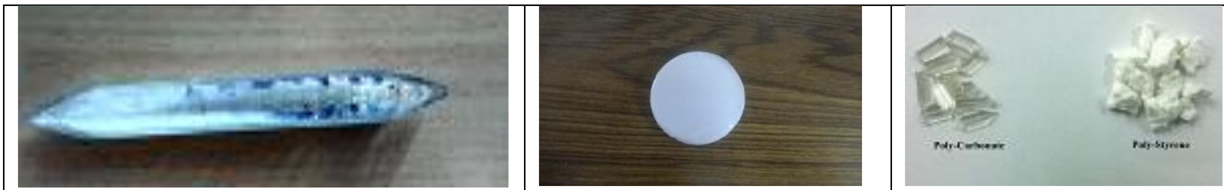

Figure 1.(a) Ingot after zone refining (b) Silicon rubber composite of cadmium iodide (c) Matrix materials polycarbonate and polystyrene

For preparation of composite material following four polymers were used as matrix materials, viz.

(1) Poly-methyl-methacrylate (PMMA)
(2) Poly-carbonate (PC)
(3) Poly-Styrene (PS)

(4) Silicon rubber (SR)

Initial pure portionwas fine grinded using agate mortar and pestle to a fine powder. No additive was used during this process. Due care was taken to keep the powder dry. PMMA granules were dissolved in chloroform (99% Fisher Scientific India) and mixed with fine powder of cadmium iodide (50% by weight). Uniform mixture was then kept to settle down for 48 hours in vibration free atmosphere. No further hot pressing was done to prevent any mechanical damaging to the sheets. After this fine sheets of PMMA-CdI_2 composite were obtained. They were cut in square sizes of 1cmX1/2 cm for further study. Sheets, without air bubble were used for the study. Poly carbonate granules [Fig1(c)] were heated and when material becomes soft, cadmium iodide fine powder (50% by weight)was mixed and stirred well. Material was cooled slowly to avoid any cracks in the material. When cooled to room temperature, material was cut into small bars of 1 cm X 1/2 cm for X-ray switching experiments. Poly–Styrene is easily soluble in acetone. Styrene granules [Fig1(c)] weredissolved in sufficient amount of acetone. Slurry formed was vigorously mixed with fine powder of cadmium iodide(50% by weight). Material was then left to settle down for 24-48 hr. Material then was cut into small plates for the switching study. Silicon rubber (code-1010) was mixed with curing agent in ratio 100:3. Mixturewas then mixed well with the fine powder of cadmium iodide(50% by weight). Material was left to settle down for 24 hr. Fine flexible sheet of cadmium iodide composite was obtained [Fig 1(b)]. Sheet was cut into small pieces for the switching studies.

Electrodes on the sheets were made by silver paste. Fine coating of silver paste was left for air drying for 1-2 hr. Sheets were then subjected to visible microscopic studies to find-out any possibility of cracks etc. Only those samples were put to studies which are free from any crack of silver electrode or otherwise.

Lay out of experimental setup used for the study of switching is shown in Fig. 2. It involves:

1. X-Ray source
2. Switching Rotor device
3. Sensor holder
4. Software /Hardware to record photo generated charge carries

Sheets were exposed to X-rays (Cu target 30KV, 10 mA plate current) parallel to electrode plates. X-ray intensity to which sheets were exposed is $4.74X10^{-2}W/cm^2$.

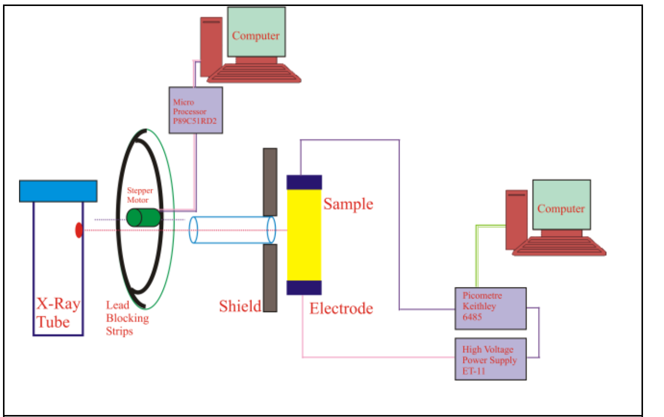

Figure 2. Lay out device set-up used to study switching characteristics of sensor material

EXPERIMENTAL RESULTS AND DISCUSSION

Composite materials are found to be better X-ray sensing materials in comparison to single crystals. Further they have good mechanical properties. This brings them in the category of technologically advantageous material. This is because they can be shaped according to the requirement. Composites of cadmium iodide have shown semi-conducting behavior with band gap ranging from 3.27-3.53 e.V. Higher band gap of these composite semiconductors has advantage to minimize current due to thermal agitation at room temperature. Further small fluctuation in temperature has minimal effect on the variation of photocurrent. Composites of PMMA, PS and PC are mechanically hard. So their mechanical handling is easy. These composites are more rigid and show extremely high stability. Composites especially of PMMA show minimum degradation with high energy radiation exposure. Rise and fall time of PC and PS composite are best among these composites. Hence these materials can be used for X-ray imaging with better advantage. It was found that photo current increases by many folds in comparison to the dark current[Fig.3]. It is found that number of charge carriers passes through the sheets of polymer and cadmium iodide composites increases with rise in temperature. This can be understood as the polymeric chain and cadmium iodide crystallites act as traps of charge carriers. With rise in temperature, phonon excitation increases. Phonon assisted hopping process helps in releasing the trapped charges. These charges using π-bond electrons move through the polymer moles to the near by cadmium iodide crystallite. Further these electrons drift under electric field through the cadmium iodide crystallites. Electric field applied to the sheet is of the order of $1 \text{ X } 10^4$ V/m sufficient enough to cause the drift.

Under the X-rays illumination photocurrent generated(I_p) is given as:

$$I_P = \frac{\xi \lambda e I_0 A(1-r)(1-\exp^{-\beta t})}{hc}$$

This clearly indicates that photo current so generated is dependent on

1. Quantum efficiency of material (ξ)
2. Area exposed (A)
3. Reflectance co-efficient (r)
4. Intensity-wave length product ($I_0\lambda$). For fixed intensity larger wavelength means more photons

Thickness of sample (t)

Composite with polystyrene show limited I_{max}/I_{min} ratio. This primarily due to benzyl groups present in these polymers. Due to higher localized electrons these polymer show higher conductivity also.

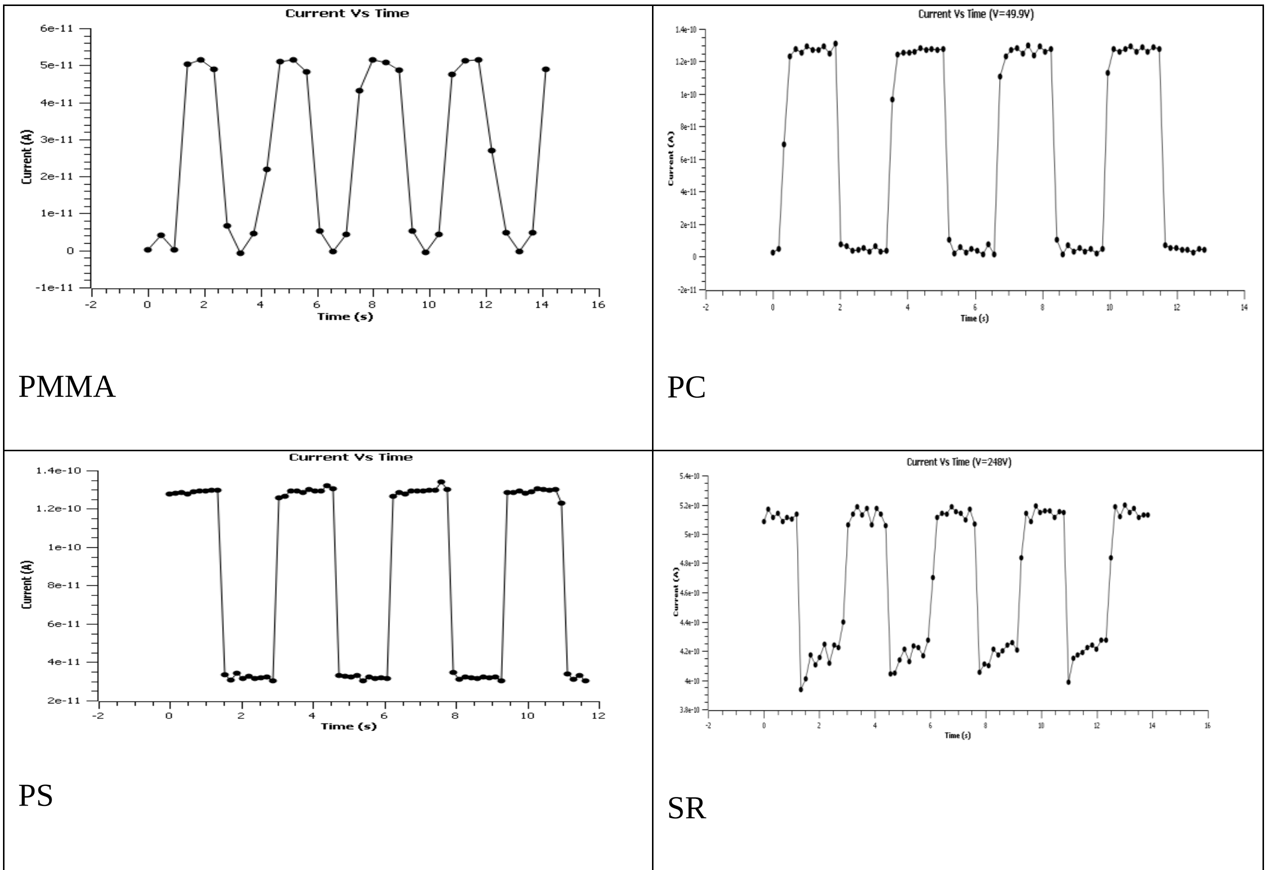

Figure 3. Switching curves of cadmium iodide composites (Electric field of the order of1 X

10^4V/m)

CONCLUSIONS

Composites of cadmium iodide are found to be better X-ray sensors in comparisons single crystals. Composites with of PMMA show minimum degradation with high energy radiation exposure. However rise and fall time during switching of PC and PS composite are best among these composites.

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